BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Caution and Warning Systems of the CM/SM and LM for AAP Case 620

DATE: November 20, 1968

FROM: A. G. Weygand

ABSTRACT

The existing caution and warning systems of the Command Module/Service Module and the Lunar Module of the Apollo Program are described. The current requirements on the overall caution and warning system of the cluster of the Apollo Applications Program are presented. The impact on the existing caution and warning systems of the Command Module/Service Module and Lunar Module resulting from implementation of these new requirements for the Apollo Applications Program are discussed. Both North American Rockwell Corporation and the Grumman Aircraft Engineering Company agree that the major cost and schedule impact items are the incorporation of:

(a) adjustable analog parameter measurement limit settings

(b) automatic reset

(c) EMERGENCY subsystem.

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SUBJECT: Caution and Warning Systems of the CM/SM and LM for AAP - Case 620

DATE: November 20, 1968

FROM: A. G. Weygand

MEMORANDUM FOR FILE

The requirements on the overall caution and warning system (CWS) of the cluster of the Apollo Applications Program are currently in a state of redefinition. Of immediate concern is the impact of these possible requirement changes on the existing hardware of the Command Module/Service Module (CM/SM) CWS and the Lunar Module (LM) CWS of the Apollo Program. The CWS's of the other modules of the AAP cluster and the interface between the CWS's of the various modules of the cluster will also be impacted by any requirements change but to a lesser degree because these portions of the overall CWS of the cluster are in a design phase rather than a hardware phase.

The inter-center Interface Control Document (ICD), 13M06022, "AAP Caution and Warning System Criteria," developed by the Apollo Applications Program (AAP) Systems Safety Panel has recently been signed by representatives of both the Manned Spacecraft Center (MSC) and the Marshall Space Flight Center (MSFC). The safety design criteria contained in this ICD differs substantially from the criteria used in the design of the CWS's of the CM/SM and LM for the Apollo Program. A description of the existing CWS's of the CM/SM's and LM's in the Apollo Program is presented in Appendix A. Since CM/SM's and LM's from the Apollo Program will be modified for use in AAP, their respective existing CWS's must be modified to meet the criteria contained in this ICD if this ICD were implemented. Up to this time, the requirements contained in Appendix B were being used by the respective vehicle contractors as the basis for the design of the interfaces between the CWS's of the various modules of the AAP cluster. It should be noted that the safety design criteria contained in the subject ICD also differ from those criteria and requirements currently being applied by McDonnell Douglas Astronautics Company Eastern Division (MDACE) as a basis for their design of the caution and warning system of the Airlock Module (AM). This CWS will also serve the Multiple Docking Adapter (MDA) and the Orbital Workshop (OWS).

In order to determine the magnitude of the cost and schedule impact of implementing these safety design criteria in the CWS's of the CM/SM and LM, MSC sent letters to the North American Rockwell Corporation (NAR) and the Grumman Aircraft Engineering Company (GAEC) in mid-July, 1968 requesting estimates

in writing to be submitted to the Apollo Applications Program Office (AAPO) of MSC of the cost and schedule impact resulting from implementation of each one of 26 criteria contained in an attachment to the letters. The content of this attachment is presented in Appendix C. Although these letters were transmitted before the date of Center sign-off of the subject ICD (mid-October, 1968), the criteria listed in the attachment to these letters generally agree with those contained in the final version of the ICD. Both NAR and GAEC have since submitted to the MSC/AAPO the requested cost and schedule impact estimates. The writer does not have copies of these responses. At this time, AAP program management at MSC is studying the NAR and GAEC responses and has as yet given no direction to either NAR or GAEC to proceed with implementation of any new criteria in the designs of the respective CM/SM and LM CWS's. It is the intention of MSC to implement these criteria on a selective basis in the CM/SM CWS and LM CWS depending on a trade-off between desirability and cost and schedule impact rather than applying these criteria across the board.

Discussion of the design of the CM/SM CWS and of the LM CWS for AAP and the cost and schedule impact of implementing some of the new criteria was conducted during the LM-A Preliminary Design Review (PDR) on October 8, 1968 and during the CM/SM Preliminary Configuration Review (PCR) on October 15, 1968, respectively. At the LM-A PDR, a Review Item Discrepancy (RID) was submitted to direct GAEC to implement all of the AAP caution and warning system criteria in the LM CWS design. The list of criteria presented in Appendix C of this memorandum was attached to the RID form. The Board of the LM-A PDR, whose responsibility is to determine final disposition of each of the RID's and to assign action as required, deferred final disposition of this RID and assigned the RID to MSC for further study. As stated earlier, MSC/AAPO is continuing study in this area.

As a result of these discussions at the LM-A PDR and the CM/SM PCR, it is apparent that both NAR and GAEC agree that the major cost and schedule impact items which would result from implementing the criteria contained in Appendix C in the CWS of the CM/SM or LM are:

(a) adjustable analog parameter measurement high or low limit settings (triggering level settings of voltage comparators and level detectors) of the CWS by the crew and/or by technicians when the module is on the launch pad,

(b) automatic reset of the CWS when an out-of-limits parameter has returned to nominal,

(c) incorporation of an EMERGENCY subsystem in the CWS.

Both NAR and GAEC believe that ajustable limit settings could not be incorporated in the existing CWS's of the CM/SM and LM without a complete redesign of the CWS of each module or, as an optimistic minimum impact, without major modification to existing CWS's requiring requalification of the modified CWS's and relocation of CWS in the CM'SM and LM. Neither NAR nor GAEC was prepared to give cost estimates during these separate reviews for incorporation of adjustable limit settings in their respective CWS's because this information was not available from their subcontractors (Autonetics for the CM/SM CWS and ARMA for the LM CWS). NAR noted, however, that the development cost of the existing CM/SM CWS exceeded 10 million dollars.

Both NAR and GAEC believed that incorporation of an EMERGENCY subsystem into the existing CWS's was unwarranted. Neither NAR nor GAEC could identify a system malfunction in their respective module which would be placed into the EMERGENCY category as opposed to the "warning" category (Appendix C) which requires a crew response time of less than 30 minutes. Both agreed, however, that a fire indication alarm would be an EMERGENCY parameter although, to date, no reliable sensors for fire detection in a weightless environment are available. GAEC estimated during the LM-A PDR that incorporation of an EMERGENCY subsystem in the LM CWS would cost between 0.8 and 1.2 million dollars. NAR made no cost estimate on this item during the CM/SM PCR because NAR believed this addition is not required in the CM/SM. However, NAR would provide a klaxon horn as part of the unit to be supplied by NAR to provide the interface between the CM/SM CWS and the CWS's of the other modules of the AAP cluster. This horn would be activated by a malfunction in the EMERGENCY category occurring in another module of the cluster. NAR estimates the cost of this unit (3 flight articles and 2 test articles) to be 0.6 million dollars. It should be noted that since a unit of similar design but without the horn is required in the CM/SM to provide an interface between the CM/SM CWS and the CWS's of the other modules whether or not the requirements of the subject ICD are implemented, it is expected that a large portion of this cost cannot be avoided.

NAR estimated that the necessary modifications to the caution detection unit (CDU) of the CM/SM CWS required to meet the AAP CWS ceiteria (Appendix C) which would include among other things automatic reset of the CWS, automatic transfer to redundant CWS power supply upon CWS power supply malfunction, and provision of different audio alarm signals for a "warning" category malfunction and for a "caution" category malfunction would cost 2 million dollars. The major cost item in this estimate is the provision of automatic reset of the CWS. GAEC was not prepared to provide an estimate of the cost of providing an automatic reset capability in the LM CWS at the LM-A PDR because this information was not yet available from its subcontractor (ARMA).

In addition to the costs of implementation for the various requirements discussed above and the cost of providing a unit to provide the interface between the LM CWS and the CWS's of the other modules of the AAP cluster which must be accepted in any case, GAEC estimates an additional 0.1 million dollars and 20 man months would be required to implement the remaining requirements of the AAP CWS criteria. These include provision of a "caution" audio alarm signal different from a "warning" audio alarm signal and provision of volume controls and cut-offs for these signals.

A. G. Weygand

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Attachment
Appendix A, B and C

APPENDIX A

DESCRIPTION OF THE CAUTION AND WARNING SYSTEMS OF THE CM/SM AND LM OF THE APOLLO PROGRAM

The function of the caution and warning system (CWS) of either the Command Module/Service Module (CM/SM) or the Lunar Module (LM) in the Apollo Program when the module is manned is to alert the crew when a malfunction of a critical system occurs or an out-of-tolerance condition exists for any of the critical parameters monitored in that respective module in order that corrective action may be taken by the crew. Upon receipt of an indication of a system malfunction or an out-of-tolerance system parameter by the CWS of either the CM/SM of LM, the crewmen in that respective module will be alerted both visually and aurally and their attention will be directed to the specific system where the anomaly occurred.

The CWS of both the CM/SM and the LM provides to the on-board crew an indication of the criticality, "caution" or "warning", of the detected system malfunction or performance out-of-limits condition. Malfunctions designated "caution" are those not requiring immediate attention but which would affect crew safety if action were not taken at some time. Malfunctions designated "warning" are those that affect immediate crew safety and require prompt remedial action. Indication of the criticality of the detected malfunction is accomplished solely by the illumination of an appropriately colored systems status malfunction indicator (annunciator) light of the caution and warning displays, amber for caution and red for warning.

A more detailed description of the CM/SM CWS and the LM CWS are presented in the following paragraphs.

Command Module/Service Module

The heart of the CWS of the CM/SM which also includes the caution and warning displays (annunciator lights and flags), switches to control CWS functions, and associated circuits to provide aural alert to the crew is the Caution Detection Unit (CDU). The CDU includes comparators, level detectors, logic, lamp drivers, a master alarm circuit, a tone generator, and redundant power supplies.

The design and fabrication of the CDU has resulted in a unit which is very inflexible. After the circuit design has been completed, all of the components of the CDU are hardwired including the logic circuitry and the fixed valued resistors which

are used to set the triggering levels of the various comparator and level detector circuits. When the CDU is received from the vendor, the unit is completely encapsulated. In the event that a change is required in the circuitry of the CDU (such as a change in the logic or in the triggering level of one of the level detectors), the entire unit must be returned to the vendor for modification. It has been estimated by the North American Rockwell Corporation (NAR) that 16 weeks lead-time is required for the vendor to make a circuit change in CDU. The CDU in its current location in the CM's of the Apollo Program is neither visible nor accessible to the crew during a CM/SM mission.

Inputs to the CDU from the instrumentation system measuring the status and performance of critical CM/SM systems consist of both analog (0-5 VDC full scale) and event (0 or 5 VDC) signals. Some signals are routed through a data distribution J-box to the CDU directly from those sensors and transducers whose voltage outputs are already in the proper range or from the Signal Conditioning Equipment which conditions the outputs of selected sensors and transducers to the proper voltage range. The data distribution J-box is provided to distribute data signals simultaneously to the CDU, the CM/SM telemetry system, and to appropriate displays on the C&D panel. Provisions are made to prevent failures in these input data lines to the C&D panel and the telemetry system from propagating to the CDU. Although the CDU was designed with provisions to accept up to 88 analog measurement inputs and a moderate number of event-type signal inputs (approximately 20), the full capability was not used in the CDU's for the CM/SM's of the Apollo Program.

All analog inputs to the CDU are applied to voltage comparators and high and low level detectors whose triggering levels have been predetermined and set using fixed valued resistors. The outputs of these circuits are routed to appropriate logic circuitry in the CDU. For the most part, event-type signal inputs are applied directly to the logic circuitry in the CDU and do not require a level detector circuit. These event-type signals originate from switch closures in malfunction detection devices which are co-located with or are part of the system being monitored. In the event of a malfunction occurring in a system being monitored by the CWS or an out-of-limits condition existing in a parameter being monitored by the CWS, the appropriate logic circuit is activated which in turn enables the applicable lamp driver circuit and routes a signal to a flip-flop circuit in the master alarm circuit to change its operating state.

The enabled lamp driver circuit in the CDU illuminates the associated caution (amber) or warning (red) system status annunciator light on the CM/SM C&D panel. The annunciator lights consist of two matrices, each containing 24 indicators. In some

cases an appropriate electromechanical event indicator (flag) on the C&D panel is also activated. The system status annunciator lights remain illuminated and appropriate flag indicators remain activated until the system malfunction or out-of-tolerance condition is corrected.

When the state of the master alarm flip-flop circuit is changed as a result of a system malfunction, either caution or warning, the master alarm circuit in the CDU is enabled. The master alarm circuit illuminates three master alarm switch-lights located at different positions on the CM/SM C&D panel, energizes an audio alarm generator in the CDU, and provides an indication to the CM/SM telemetry system for transfer to the Manned Space Flight Network (MSFN) and the Mission Control Center (MCC). The output of the audio alarm generator is a square wave that is alternated between 750 Hz and 2000 Hz at a rate of 2.5 times per second. The output of the alarm generator is routed separately to the headsets of three crewmen via paths independent of the normal voice communications circuits and volume controls. The volume of this audio alarm signal is preset at a level which permits conduct of voice communications between the crewmen.

Depression by a crewman of any one of the three master alarm switch-lights extinguishes the master alarm switch-lights, deactivates the audio alarm generator, removes the indication previously sent to the telemetry system, and resets the flip-flop circuit in the master alarm circuit. This action in no way affects the state of the system status annunciator lights. It should be noted, however, that when a system status annunciator light has been activated by one of several possible malfunctions and the master alarm flip-flop circuit has been reset, any additional malfunctions occurring associated with the same logic and annunciator light will not activate the master alarm circuit unless the first malfunction had been previously corrected. A manual switch is provided for use after CM separation from the SM which prevents malfunction signals and annunciator lights associated with SM systems from remaining active.

The CWS is used to provide a controlled call capability whereby the MSFN can attract the attention of the crew in the CM by triggering the master alarm circuit of the CDU and illuminating an appropriate system status annunciator light with an event signal which enters the CDU from the up-data link portion of the CM/SM Unified S-Band communications system. Although the master alarm circuit can be reset by the crew, the associated annunciator light can only be extinguished by a second event signal sent by the MSFN via the up-data link.

A switch is provided on the CM/SM C&D panel to enable the crew during the CM/SM mission to test the lamps of the annunciator lights and the master alarm switch-lights. It should be noted that there are at least two lamps per annunciator light.

The CWS receives prime power from two 28 VDC buses through diodes and circuit breakers. Closure of either circuit breaker will permit normal CWS operation. The regulated DC voltages required for operation of the CWS electronics and electrical equipments are provided by redundant power supplies located in the CDU. Each of the redundant power supplies includes the appropriate sensors and the capability to illuminate an annunciator light providing an indication to the crew of a CWS power supply malfunction (high or low output voltage). The audio alarm generator will not be activated. After a CWS power supply failure, the crew must manually select via a 3 position switch the redundant power supply to return the CWS to operation.

Lunar Module

The heart of the CWS of the LM which also includes the caution and warning displays (annunciator lights and flags), master alarm switch-lights, an audio tone generator, and a CWS light and tone test switch is the Caution and Warning Electronics Assembly (CWEA) which contains all of the logic for the LM CWS.

The CWEA consists of a number of individually encapsulated modules called "sticks" which are hardwired (as opposed to plug-in connectors) to the terminal blocks of a chassis. Each "stick" is individually designed and contains the necessary level detectors and logic required to meet a specific system malfunction sensing requirement. All necessary interconnections of the logic in two or more sticks will also be provided through hardwired connections. The fixed valued resistors controlling the triggering level of the level detectors are located in each stick such that they may be replaced after a small portion of the encapsulant has been removed without removing the affected stick from the CWEA. However, such a modification will require removal of the CWEA from the LM. The current location of the CWEA in the LM's of the Apollo Program does not permit crew access during the LM mission.

Inputs to the CWEA describing status of critical LM systems consist of both analog (0-5 VDC full scale) and event (0 or 5 VDC) signals. These signals are provided directly from those sensors and transducers whose outputs are 0 to 5 VDC full scale or from the Signal Conditioning Electronics Assembly (SCEA) which conditions the voltage outputs of certain transducers (e.g., temperature sensors) to the 0 to 5 VDC range. The output of the same sensor and/or transducer is used to drive displays on the LM Control and Display (C&D) panel, for inputs to the LM telemetry system, and for inputs to the LM CWS system. However, appropriate buffering is supplied to protect the data input to the CWEA from possible electrical shorts occurring in the data input lines to the C&D panel and/or telemetry system. The number of possible inputs to the CWEA is restricted by the volume of the various sticks which is a function of the complexity of the logic. For the LM's in the Apollo Program there are approximately 120 measurement (analog and digital) inputs to the CWEA.

All inputs to the CWEA are applied to high and/or low level voltage detectors whose triggering levels have been predetermined and set using fixed value resistors. The outputs of the various level detectors are routed to various logic circuits. A logic "one" from any logic circuit is an indication of a system malfunction. Upon detection of a system malfunction, a signal is sent to enable a relay driver circuit located in the C&D panel area and a signal is sent to a master flip-flop circuit located in the CWEA to change is operating state.

The enabled relay driver circuit energizes a relay whose closed contacts provide excitation or illumination of a systems status annunciator light located on the LM C&D panel. Two banks of indicator lights, each containing twenty lights, are provided on the LM C&D panel. One bank has amber lights and the second bank has red lights. Each of these indicator lights will be illuminated only in the event of a specific malfunction (or when all indicator lights are tested for operability in-flight checkout). The bank of red lights is used to alert the crew of a specific system malfunction in the "warning" category while the bank of amber lights is used to alert the crew of a system malfunction in the "caution" category. These indicator lights remain illuminated until the system malfunction is corrected, an "inhibit" signal is sent ot the logic of the CWEA, or a "reset" signal is sent to the logic of the CWEA. It should be noted that not all of the logic circuits are capable of receiving "inhibit" and/or "reset" signals.

Reset capability is provided in any logic circuit which monitors a number of different subsystems but can only illuminate a single annunciator light. Consequently, after the specific subsystem which has malfunctioned out of the many whose status is reflected by the illuminated annunciator light has been determined by a crewman, the crewman can reset the logic by actuation of the proper control (usually a rotary switch associated with the affected subsystem) to enable the logic for detecting and alerting the crew of a malfunction of a different one of the group of monitored subsystems.

An inhibit capability is provided in selected logic circuits where an out-of-limits condition may exist but a malfunction indication is no longer wanted. For instance, the logic circuits which are used for monitoring system located in the descent stage of the LM's used in the Apollo Program are provided with an inhibit capability which is automatically exercised when the descent stage is jettisoned to prevent failure alarm and annunciator light actuation when the monitored systems have been jettisoned. Inhibit signals cannot be specifically generated by the crew but are generated as a result of performance of some action automatically or by the crew which is directly related to the controls of the affected system which changes the system configuration.

When the state of the master flip-flop circuit is changed as a result of a system malfunction, either caution or warning, the master relay driver circuit located in the C&D panel area is enabled which actuates specific relays and a signal is sent to the LM telemetry system for transfer to the MSFN and MCC. As a result two master alarm switch-lights located in different areas of the C&D panel are illuminated and an audio tone generator is energized. The output of the tone generator is a 3000 Hz tone and is routed separately to the headsets of the two crewmen via paths independent of the normal voice communications circuits and volume controls. The volume of the audio alarm tone is preset at a level which permits conduct of voice communications between the crewmen.

Depression by a crewman of either one of the two master alarm switch-lights extinguishes the master alarm switch-lights, deactivates the audio tone generator, removes the caution and warning master alarm signal from the LM telemetry system and resets the master flip-flop circuit enabling the crew to be alerted both aurally and visually if another system malfunction should occur. Depression of the master alarm switch-light in no way affects the state of the caution or warning annunciator lights.

A rotary switch is provided on the LM C&D panel to enable the crew during the LM mission to test the operability of all of the caution and warning annunciator lights, of the audio tone generator, and of the light portion of the master alarm switch-light.

Although different power supplies are used to provide power to different portions of the LM CWS (e.g., tone generator, inhibit signal, CWEA, etc.), none of these power supplies has a back-up. The prime power to the power supply of the CWEA is provided by only one of the 28 VDC power buses of the LM through an appropriate protective device. The crew will be alerted by the CWS if the power supply of the CWEA has malfunctioned.

APPENDIX B

CLUSTER CAUTION AND WARNING SYSTEM (CWS) TONE REQUIREMENTS

1. The CWS in any vehicle must be individually displayed and also turn on the CWS and tone in all other vehicles simultaneously.

2. The CWS tones in any vehicle will not be common electrically or cross an interface.

3. CWS tone interface between vehicles shall be a discrete switch closure.

4. The CWS tone system shall not propogate an echo tone between vehicles, i.e., the "DOMINO" effect.

5. CWS reset shall be performed in the originating vehicle which shall turn off all associated remote tones and lights. However, each vehicle can reset its own master CWS tone, but the advisory lights shall remain lit until the originating CWS activation is acknowledged.

6. No CWS tone shall be wired through EVA umbilical.

7. A wakeup or call signal will be implemented via the CWS tone. The CWS in any vehicle may be manually activated from any other vehicle for this purpose.

8. A single inadvertent ground shall not jeopardize any CWS tone path.

9. The CWS tone circuits shall conform to applicable EMI requirements.

APPENDIX C

AAP CAUTION AND WARNING SYSTEMS CRITERIA

The Apollo Applications Program Office has formulated a Caution and Warning Systems Criteria applicable to new system design. Where vehicles or systems are already in existence, application of the criteria will be considered on a case-by-case basis.

The Caution and Warning System (CWS) shall be composed of three subsystems: EMERGENCY, warning and caution. The EMERGENCY subsystem shall interface with the caution and warning subsystem by means of discrete contact closures.

1. A Caution and Warning System shall be installed in each vehicle associated with the cluster mission. The interconnection between vehicle caution and warning systems shall be by means of discrete contact closures.

2. The Caution and Warning System of each vehicle docked to the cluster shall be interconnected in such a manner as to operate as an integrated system while connected. Indications foreign to any vehicle shall be inoperative when such vehicle is operating independently.

3. Each Caution and Warning System shall consist of sensors control and display panel(s), and signal generator(s) as appropriate.

4. Each Caution and Warning System must be protected by suitable individual protective devices, be the only item on that protective device, and be capable of drawing power from two or more independent, normally energized busses without action required from the crew.

5. No raw unprocessed signals or display information shall be routed across a vehicle interface.

6. All Caution and Warning Systems shall be compatible with AAP electromagnetic interference requirements.

7. Each Caution and Warning System shall have a built-in capability to permit system testing by a crewmember. Provision will be made to permit end-to-end checkout of the EMERGENCY system (transducer to light and Klaxon test).

8. A manual guarded signal generator cut-off capability shall be provided in each Caution and Warning (and EMERGENCY) System.

9. The sensors of the Caution, Warning and EMERGENCY Subsystems shall monitor defined parameters and shall cause a signal, as appropriate, to be generated in response to defined off-nominal values of such parameters.

10. The EMERGENCY signal is isolated from the caution and warning subsystems but will activate the tone and indicator lights of the Caution and Warning System in addition to sounding its own acoustic signal.

11. The caution tone will be different from the warning tone.

12. When generated, a caution and warning signal shall cause within its own system:

    a. Illumination of the Master Alarm Light (red).

    b. Illumination of a caution (amber) or warning (red) signal light, appropriately titled to indicate the source or sources of the off-nominal condition.

    c. Activation of a signal generator.

    d. Generation of an intervehicular signal (discrete contact closures) to each of the other interconnected monitoring systems.

13. The Master Alarm Light and audio signal shall be so designed that they may be manually reset.

14. The light indicating the off-nominal parameter shall remain illuminated until the fault has been removed.

15. The intervehicular signals will be treated as warning or as caution signal as appropriate by the receiving monitoring systems and shall result in illumination of signal lights titled to indicate the identity of the vehicle in which the signal was originated, in addition to the Master Alarm Light and signal generator.

16. System reset capability shall be provided to perform reset by depressing the Master Alarm reset. Depressing the Master Alarm reset after a caution or warning associated with that Caution and Warning System has been indicated shall accomplish the following simultaneously:

    a. Turn off the Master Alarm Light on each caution and warning system panel.

b. Turn off the tones and EMERGENCY signals if triggered.

c. Extinguish all location lights on each caution and warning system panel except the one light that identifies the cause of caution or warning.

d. Place system in a ready state to accept another caution or warning.

Once repair or adjustment has removed the malfunction the light identifying the malfunction as well as any associated lights in other vehicles that have not been reset shall be reset.

17. Non-reset capability - design of reset system shall be such that depression of Master Alarm Light at locations outside of the originating vehicle shall turn off the tone, alarm signal and Master Alarm Light in that vehicle only, and leave the "vehicle" light illuminated.

18. Independent controls must be provided in each monitoring system for amplitude adjustment of the signal generator. The minimum adjustment fo these controls shall be greater than zero (audible above noise level).

19. Caution and warning signals shall be fed to earphones and loudspeaker boxes via separate wires from those employed by the communications or intercommunications systems and shall bypass crewmembers' individual volume controls. The signal shall also bypass or override sleep switches.

20. No signal associated with a vehicle's Caution and Warning System shall be supplied to a crewman engaged in EVA, either through umbilical wiring or as part of a RF link. The use of a signal associated with the monitoring of an extravehicular crewman's own life support or associated systems is not precluded by this section.

21. Criticality and/or crew response will be used to determine if a parameter is categorized as caution, warning, or EMERGENCY.

22. A manual trigger capability shall be provided on each caution and warning panel to permit a crewmember to sound a warning in cases where desired or necessary.

23. The number of caution and warning or EMERGENCY parameters must be maintained at the absolute minimum consistent with crew safety.

24. Analog parameters associated with the Caution and Warning Systems must have adjustable limit settings and systems response time to prevent inadvertent caution and warning signals being generated by transients.

25. The EMERGENCY and Caution and Warning Systems must provide telemetered data that will indicate which vehicle has caused the Caution and Warning System to be activated. This data must remain "on" until all indicator lights are extinguished.

26. The EMERGENCY subsystem may be required to furnish switching functions for control of other systems or components associated with hazard corrective action. These interconnection must be designed so that EMERGENCY system reliability is not degraded and in such a fashion that the interconnection may be manually interrupted (switched out) by the crew if required.

Definitions: The following definitions apply:

a. Vehicle - The smallest configuration or modules (one or more) capable of independent operation, manned or unmanned, and capable of being manned. (Example: CSM, MDA/AM/OWS)

b. Cluster - That assembly which is composed of the MDA/AM/OWS and one or more vehicles docked to it.

c. Mission Critical Condition - Any condition that is hazardous to the flight crew or will cause a premature termination of the mission.

d. EMERGENCY - Signal denotes an extreme crew hazard requiring immediate action. It is an acoustical signal generated by an electro-mechanical or mechanical device such as a bell or a Klaxon, that is propagated within the atmosphere of a vehicle without regard to any of the components of the intercommunication system.

e. A warning signal is one that is indicative of an existing or impending mission critical condition requiring corrective action (requires a crew response time of less than 30 minutes).

f. A caution signal is one that is indicative either of an impending mission critical condition or one that would result in loss of a significant capability of the vehicle. (Requires a crew response time of 30 minutes to two hours). Addition of parameters that satisfy the caution criteria but with response time of two to eight hours will be considered for inclusion on a case-by-case basis.

g. Status signal - A status signal is a meter indication, system flag, indicator light, or telemetered information. Status signals are used during normal operations and for systems troubleshooting since they provide the maximum systems data; they are not a part of the Caution and Warning System as such. (Status signal is not part of Caution and Warning System).

h. A caution and warning system is a system that monitors the performance of itself and other systems in such a fashion as to generate, to display, and to alert the crew to the existence of defined caution and warning signals.

i. A master alarm light is a red indicator light whose illumination denotes the generation and existence of one or more caution and/or warning signals.

BELLCOMM, INC.

Subject: Caution and Warning Systems of the CM/SM and LM for AAP

From: A. G. Weygand

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